Reconstruction of Objects from Optical Images and the Number of Degrees of Freedom of an Image

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ROBERT R. SHANNON, *Presider*

Image Enhancement

Contributed Papers

ThC11. Generalized Sampling Criteria in Image Synthesis. F. T. S. YU AND R. D. BARNARD, *Electrical Engineering Dept., Wayne State University, Detroit, Mich. 48202.*—At the present stage, most of the image-synthesis techniques use the standard Shannon sampling theorem. We will propose, as an alternative to the present minimum-redundancy technique, a more-generalized sampling theorem that would require fewer sampling elements. Futhermore, based on the prescribed element design criteria and image-reconstruction specifications or constraints, techniques for image synthesis by generalized sampling theorems will be developed. (13 min.)

ThC12. Reconstruction of Objects from Optical Images and the Number of Degrees of Freedom of an Image.* B. J. HOENDERS (introduced by E. Wolf), *Dept. of Physics and Astronomy, University of Rochester, Rochester, N. Y. 14627.*—The usual approaches to the problem of determining the number of degrees of freedom of an image (based on the Whittaker–Shannon sampling theorem), formed by an aberration-free system in coherent illumination are analyzed and are shown to be incorrect. Another method is developed, using a new sampling theorem in which the sampling points can be chosen arbitrarily in that part of the image plane that is accessible to measurement. The Whittaker–Shannon theorem is found to be a special case of this new sampling theorem. Another sampling theorem will also be derived, which applies to imaging by a general (non-isoplanatic) optical system. We consider further an optical system with an arbitrary number of aberrations and describe a procedure for determining the wave function in a plane intercepting the light emerging from the object, from the contrast in the image plane. This result implies that phase information is not needed for the reconstruction. (13 min.)

* Research supported in part by the Air Force Office of Scientific Research.

ThC13. Application of Enhanced Space-Autocorrelation Function to the Analysis of Random Scenes. E. GARCIA AND H. STARK, *Engineering and Applied Science Dept., Yale University, New Haven, Conn. 06520.*—The space-autocorrelation function (SAF) is useful in yielding information about the magnitude and orientation of strongly correlated features in random scenes. In practice, the SAF is difficult to obtain. We describe here a technique for obtaining an enhanced SAF, meaning that its nondifferentiable regions are strongly highlighted. The Fourier irradiance spectrum of a scene is photographically recorded in a coherent-optical configuration. The film is processed in a manner that yields an extremely low gamma. This has an effect equivalent to companding or high-frequency enhancement, permitting a recording of spatial frequencies over a wide range with little loss of information. When the recording film so processed is optically Fourier transformed, the resulting irradiance distribution is the enhanced SAF. The application of this enhanced SAF is illustrated by showing how it can be used to bring out hidden periodicities in random scenes, with the complex random checkerboard as an example. (13 min.)

ThC14. Fourier-Transform Method of Image Restoration.* D. D. DUNCAN, R. S. DAVIDSON, AND S. A. COLLINS, JR., *The Ohio State University ElectroScience Laboratory, 1320 Kinnear Rd., Columbus, Ohio 43212.*—The Fourier-transform method of restoring atmospherically degraded images is a well-known technique that requires a point-reference source near the object. Calculations have been performed that examine the distances between object and reference source that will provide satisfactory restoration. The calculation is divided into two parts, the first of which relates atmospheric and geometric parameters to wavefronts entering a telescope. The second part relates wavefront parameters to measures of image quality. Results will be given for various geometries and types of degradation. (13 min.)

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ThC15. Information Leakage through a Passive Optical Channel. F. T. S. YU AND ANTHONY TAI, *Electrical Engineering Dept., Wayne State University, Detroit, Mich. 48302.*—From a basic entropy viewpoint, the information leakage through a passive coherent optical channel is derived. In the cause of derivation, the optical channel may be decomposed into cascade subchannels. It is shown that the mutual information decreases as the optical signal proceeds through the channels. The result as applied to optical-image enhancement is illustrated. Some basic constraints upon coherent optical-processing technique will also be discussed. (10 min.)

ThC16. Point-Spread Functions and Image Restoration with Astigmatism and Curvature of Field.* ALEXANDER A. SAWCHUK, *Dept. of Electrical Engineering, University of Southern California, Los Angeles, Calif. 90007.*—When astigmatism and curvature-of-field aberrations are present, the point-spread functions that describe the degradations of linear incoherent-imaging systems are space variant. From a knowledge of the aberration functions of geometrical optics, the space-variant response is derived. By taking advantage of the particular structure of these aberrations, the spatial dimensionality of the image-restoration problem is significantly reduced, and systems of equations in four spatial variables can be solved.[1] For astigmatism, restoration involves coordinate transformations on the image followed by solution of a family of identical equations for a one-dimensional space-invariant degradation. The restoration for curvature of field is similar but requires an additional space-invariant solution. The solution is obtained by pseudo-inverse and minimum-variance estimates using singular-value decomposition techniques. Some examples of digital-computer implementation will be presented. (13 min.)

* Research supported by the Advanced Research Projects Agency of the Dept. of Defense and monitored by the Air Force Eastern Test Range.
[1] A. A. Sawchuk, J. Opt. Soc. Am. **64**, 124 (1974).

ThC17. Spatial Filtering of Moiré Plots. JAMES S. MARSH (introduced by R. C. Smith), *Physics Dept., University of West Florida, Pensacola, Fla. 32504.*—Contour plots of two-dimensional functions are produced as moiré fringes from the overlay of a computer-generated function grid and a reference grid. Individual grid lines are removed by spatial filtering of the diffraction pattern of the plot, leaving behind only the contours. It is observed experimentally and verified theoretically that the contour lines are sharpened by forming the image with the first order and the neighboring sideband of the zeroth order of diffraction pattern of the plot. (13 min.)